The political economy of molecules: vital epistemics, desiring machines and assemblage thinking

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The Political Economy of Molecules:

Vital Epistemics, Desiring Machines and Assemblage Thinking

Abstract

Could the most miniscule of objects, imperceptible to the human eye, enact whole new political economies? The suggestion may seem odd, but this article reveals how tiny molecules are already engendering new regimes of value across the fields of global health and biodefense. Delving genealogically into the onto-epistemology of the life sciences, the article traces the protracted *molecular* reconfigurations of state-market relations underpinning the global bioeconomy and civilian biodefense today. Using methodological precepts developed through assemblage thinking, this evolving patchwork of new constellations is conceptualized as a global molecular assemblage. Attending to this lively play of molecules in the world, the article argues, advances the post-Foucauldian, molecular study of biopolitics by exploring how scientific shifts in our 'vital epistemics' contour state-market relations. It further contributes to the development of a post-human international political economy that is more sensitive to the ways in which artefacts (like molecules) too exhibit particular kinds of 'agency' and 'force' in the world. Finally, it enhances the field's ability to make unconventional, hitherto overlooked, and multi-scalar connections in the study of political economy through the creative use of assemblage thinking. In the case of molecules, such assemblage thinking can – quite literally – reveal the value of 'life'.

Keywords:

- molecular
- bioeconomy
- assemblages
- medical countermeasures
- global health security

Economics is how lifeforms organise their enjoyment.

– Timothy Morton, *Humankind* (2017)

Introduction

New molecules can possess the most unusual of names. Before they are worked up into fully-fledged pharmaceutical products suitable for human consumption, they are often identified solely by a short combination of letters and numbers associated with the company that first developed them. ST-246 is one such molecule developed by a comparatively small US pharmaceutical company called Siga Technologies. A few years ago, their new molecule caught the eye of the Biomedical Advanced Research and Development Authority (BARDA) – a specialized US government agency tasked with procuring new pharmaceutical defences against health-based threats such as pandemics, bioterrorism and anti-microbial resistance. BARDA was interested in ST-246 because the molecule showed promising activity against the smallpox virus, which the US government had become concerned about as a potential weapon of bioterrorism. If it were possible to develop this promising new molecule into a viable pharmaceutical product, then the US government could add it to its burgeoning national stockpile of 'medical countermeasures' protecting the population and economy against biological danger.

There was just one catch; and it was a big one. A lot of costly and technically complex advanced development work would still need to be carried out in order to transform ST-246 into a safe and effective medical countermeasure. Clinical trials would first have to be carried out. Approval from the official regulatory agencies, like the U.S. Food and Drug Administration (FDA), would need to be secured. Mass production facilities would also have to be designed for manufacturing and stockpiling the new pharmaceutical product at high volume. As a comparatively small biotechnology company (with only around 65 employees at the time), Siga Technologies possessed neither the work force, the finances, nor the technical expertise to carry out all this advanced development work on its own (Love 2011). 'Drug development is such a capital-intensive process', Kaushik Rajan explains, 'that very few companies have the muscle to actually take a drug to market' (Rajan 2006: 45). To become a viable new medical countermeasure against the smallpox threat, ST-246 would require extensive outside support.

At this point, and rather than abandoning the fate of ST-246 to the vagaries of commercial markets alone, the US government decided to step in. Despite the country's public valorisation of 'free' markets and laissez-faire capitalism, the government directly intervened into the play of

market forces and, in 2011, officially supported Siga Technologies with the advanced development of ST-246 through a 5-year contract worth US$ 433 million (HHS 2011). That decision rendered ST-246 one (and a rather illustrious) example of a growing number of molecules passing through a new, multi-faceted and increasingly extensive public-private pharmaceutical regime that has been designed in the United States for the specific purposes of developing novel 'medical countermeasures' against biological threats. How does the political economy of this new medical countermeasures 'enterprise' differ from more conventional approaches to drug development in the fields of global health and biomedicine? What role did molecular knowledges developed in the life sciences play in brining about the significant transformations of state-market relations that now underpin this new medical countermeasures enterprise? What, moreover, becomes of international political economy when we commence its study not with macro-structures like states or markets – but with the tiniest of molecules like ST-246?

This article argues that molecules are highly pertinent, powerful and even generative 'actors' in international political economy. The article develops this argument by showing, first, how a substantial proportion of the world economy today revolves around the commercialization of biological products and processes – what political economists variously refer to as the 'bioeconomy', 'biovalue', 'biocapital' or simply 'biotech' (Birch and Tyfield 2013). The article next undertakes a closer genealogical interrogation of the 'bio' residing at the heart of this global bioeconomy, revealing that it actually entails a very particular onto-epistemic shift towards the 'molecular' in the life sciences. The global bioeconomy is, in fact, a political economy of molecules. Using key methodological precepts developed through assembling thinking – such as exterior relationality, heterogeneity, and multi-scalarity – the article then advances an original conceptualization of this global bioeconomy economy as a diverse, dynamic, and desire-driven molecular assemblage. Finally, the article traces how this open-ended global molecular assemblage is already evolving further because governments want to harness the power of molecules for the additional purposes of strengthening civilian biodefense by developing a range of new medical countermeasures. In mapping, tracing and analysing how the onto-epistemic shift towards a molecular vision of life is triggering protracted reconfigurations of state-market relations across the fields of global health and national security, the article is thus able to uncover the distributed 'enrolment' power that molecules exert in international political economy today.

Attending to this lively play of molecules in the world has wider ramifications for the study of international political economy. Demonstrating how recent shifts in our 'vital epistemics' are re-contouring state-market relations in subtle but powerful ways advances the post-Foucauldian, molecular study of biopolitics. Revealing the 'agency' that non-human artefacts and objects – like

molecules – exert during those processes helps to cultivate a post-human international political economy that remains more sensitive to the intricate connections between human life and the wider natural world. Teasing this 'power' of molecules out methodologically, moreover, also develops assemblage thinking as a creative approach for making unconventional, hitherto overlooked, and multi-scalar connections between processes, actors, objects, and knowledges in the study of international political economy. In the case of molecules, such assemblage thinking can – quite literally – reveal the value of 'life'.

1. Bio-Capitalizing: Bio-value, Bio-capital, and Bio-economies

That our biological existence is integral to international political economy has been known at least since Michel Foucault showed how the development of capitalism in the 17th and 18th centuries witnessed the entering of human life 'into the order of knowledge and power, into the sphere of political techniques'. For the first time in history, he famously argued, biological existence was reflected in political existence, giving rise to a new form of biopower. 'Without question', Foucault further asserted, such biopower was 'an indispensable element in the development of capitalism', because 'the latter would not have been possible without the controlled insertion of bodies into the machinery of production and the adjustment of the phenomena of population to economic processes' (Foucault 1978: 14). In *The History of Sexuality* he could thus convincingly demonstrate that society, politics, and economics are deeply enmeshed with our 'biological' life through a biopower manifesting along two principal axes – the micro-level of the individual human body (anatomo-politics), and the macro-level of the population (biopolitics).

Since those influential works were penned, however, the 'biological' has become pertinent to international political economy in other, and arguably even more direct, ways. Advances in biotechnology mean that the 'biological' is now itself also a site of capitalist value creation – from the development of new drugs for biomedicine and global health, through to the design of innovative approaches to food, energy and textile production. Improved scientific understanding (and control) of biological processes has incited a plethora of new regimes for creating 'bio-value'; and a swarm of private biotechnology companies have already secured venture capital in order to seize upon those seemingly boundless commercial possibilities (Franklin 2000; Waldby 2002; Vettel 2006; Helmreich 2008). Collectively, those activities have engendered a whole new 'bioeconomy' that is 'based on the use of research and innovation in the biological sciences to create economic activity and public benefit' (White House 2012: 7). All of this marks a quite significant change in the role that the biological plays in the world economy today. Whilst 'the capitalist economy has

historically sought to capture the surplus labour power of individuals', Parry and Greenhough (2017: 12) argue, 'new ventures now seek to extract value from commercializing access to biological products and processes themselves'.

Governments and international organizations have evolved their economic strategies in order to actively transform this bio-revolution into a new engine of macro-economic growth (Petersen and Krisjansen 2015). The Organization for Economic Cooperation and Development (OECD) and European Commission, for example, explicitly pushed for the introduction of biotechnology into new economic platforms and partnerships; and they have buttressed a whole new 'bioeconomy' capable of capturing 'the latent value in biological processes … to produce improved health and sustainable growth and development' (OECD 2005: 5, cited in Cooper 2008: 45). In the United States, the Obama Administration's 2012 *National Bioeconomy Blueprint* similarly proclaimed that developing the U.S. bioeconomy could 'allow Americans to live longer, healthier lives, reduce our dependence on oil, address key environmental challenges, transform manufacturing processes, and increase the productivity and scope of the agricultural sector while growing new jobs and industries' (White House 2012: 1). Determining the exact size of this bioeconomy is difficult due to limitations with current data collection and classification, and because so much depends upon precisely how this bioeconomy is analytically delimited for the purposes of measurement (Carlson 2016; Wesseler and von Braun 2017). Yet recent reports already place the estimated value of this bioeconomy at more than $353 billion in economic activity in the United States alone (in 2012), whilst the European Commission estimates that the European bioeconomy (excluding health applications) is worth more than €2 trillion annually and employing in excess of 21.5 million people (see CIB 2015).

Governments have also provided extensive public support to this burgeoning bioeconomy through a range of economic strategies. Large amounts of public funding were made available to the life sciences in order to improve the scientific understanding of biological processes. In the United States, for example, the US National Institutes for Health (NIH) played a prominent leadership role in sequencing the human genome – reflecting a much broader trend whereby 'the entire history of molecular biology' is one 'of federal funding of "basic research" that was meant to create the technical base necessary to understand and cure diseases' (Kenney 1986: 241). The US government also introduced new legal frameworks to enable closer ties between academic research organizations and industry, so as to facilitate the smooth and rapid movement of emergent biological knowledges out of the life sciences and into the wider economy. The 1980 Bayh-Dole Act, for instance, aided such commercialization of basic scientific research by effectively allowing federal grantees (like scientists, universities and corporations) to patent and license discoveries resulting

from publicly funded research (Owen-Smith and Powell 2004; Rajan 2006:6; Helmreich 2008: 471; Hurt 2011; Vallas, Kleinman, and Biscotti 2011: 57). New juridical regimes have since also been developed (and expanded) in order to enable intellectual 'property' to become attached to these knowledges in the life sciences, and for such intellectual property claims to be asserted internationally via the World Trade Organization and TRIPS (Sell 2003; Rajan 2006; Williams 2012; Hilberg 2015).

Such government support for the bioeconomy has not at all been confined to the United States and Europe. Joseph Wong's *Betting on Biotech* documents in detail how governments in several Asian countries (notably Korea, Taiwan and Singapore) similarly provided an active array of public support for the bioeconomy, even if that support took different forms in different national contexts (Wong 2011). Further studies show that other geopolitically pivotal countries – like India, China and Russia – have similarly invested heavily in nurturing the bioeconomy (Rajan 2006; BioStep 2018). In fact, more than 20 countries across the Americas, Europe, the Asia/Pacific and Africa have already developed strategies that explicitly identify the biotech sector as being critical to their future economic and employment growth (Carlson 2016: 247; BioStep 2018). Furthermore, all of those efforts have also been accompanied by geographically much broader global health initiatives, launched in the aftermath of the global AIDS pandemic, seeking to distribute the 'fruits' of this bioeconomy more equitably with *all* populations around the world – by expanding international access to medicines (like anti-retroviral therapy), and by developing new medicines for diseases prevalent in in low-income countries. Extensive support from governments around the world has given the bioeconomy increasingly global scope.

Dominant tropes of 'free markets', 'venture capital', and an intensely 'entrepreneurial' biotechnology industry notwithstanding, then, governments and international organizations actually played a critical role in facilitating the rise of the 'bioeconomy' and in sustaining global 'biocapital' (Vallas, Kleinman, and Biscotti 2011). As Mariana Mazzucato argues more generally in *The Entrepreneurial State,* governments have played a highly pro-active role in nurturing the bioeconomy, and the private sector has mostly invested only *after* an 'entrepreneurial' state first made the initial, high-risk investments (Mazzucato 2013: 66). Focusing solely on the 'mutual imbrications of capital and biology' in the global bioeconomy, Rebecca Hester (2016: 176) rightly argues, would be to ignore 'the role of the state in provoking those entanglements'. Just as the wider economy has always required government investments in public goods, ranging from infrastructure to national security, so too the global bioeconomy is indisputably a *political* economy characterized by deeply entangled state-market relations (Rajan 2006).

2. Vital Epistemics: The Molecular Vision of Life

A few pioneering scholars have begun to probe the ramifications of this burgeoning bioeconomy for the wider study of political economy. Melinda Cooper sensitises her readers to the strong market dynamics at play in what she calls 'life as surplus', and she firmly contextualizes the rapid rise of the biotechnology industry within the rise of neo-liberalism more broadly (Cooper 2008: 19). 'The biotech era', she argues, 'poses challenging questions about the interrelationship between economic and biological growth, resurrecting in often unexpected ways the questions that accompanied the birth of modern political economy' (Cooper 2008: 3). Kaushik Sunder Rajan takes a different approach by comparing the new regimes of value engendered in the area of biomedicine in the United States and India (2006; 2012; 2017). Eschewing an overtly epochal account, Rajan develops the notion of 'biocapital', which 'simultaneously manifests as a specific *case study* of systems of capitalism – one situated lens through which we can view the emergence of capitalist logics and systems writ large – and a *particular form* of capitalism made specific because of emergent technologies and epistemologies of the life sciences' (Rajan 2006: 78). Those early and ground-breaking accounts of the bioeconomy remain highly compelling; yet framing all these developments merely as the 'bio' ultimately also occludes as much as it captures. Although it has become pervasive now, this 'bio' framing does not tell us very much about the precise nature of the 'biological' that resides at the heart of this global bioeconomy.

Interrogating the 'bio' genealogically reveals that it actually entails a very particular and specific way in which the life sciences now understand the 'biological' predominantly in *molecular* terms (Kay 1993, 2000; Rose 2007; Elbe 2014; Hester 2016). The scale at which we can understand (and manipulate) the 'biological' has thus become progressively smaller over the past century – moving first from the level of the human body to the inner workings of the cell, and later burrowing even deeper to the scale of individual atoms embedded in their respective molecular groupings. Scientific techniques like x-ray crystallography eventually even allowed the exact molecular structure of DNA to be revealed and visualized, all of which played such a crucial part in the discovery (in 1953) that the DNA molecule exists in the form of a three-dimensional double helix (Pray 2008: 100). DNA sequences can now represent biological life in terms of a manipulable string of molecular information expressed in quite simple – if also extremely long – code (Abir-Am 1992; Dillon and Reid 2001). That realization, Michael Kenny (1986:2) argues, would form the 'key discovery on the road to the creation of biotechnology'.

The rise of the global bioeconomy thus relies upon what is in fact a critical *double* movement in relation to the 'biological' – or what Karen Barad in a very different context (2007: 43; 185) calls a

new ‘onto-epistemology’. In a first step, the molecular vision of ‘life’ asserts an *ontology* because it construes ‘life’ as being fundamentally governed by underlying biological processes. This endows ‘life’ with a (new) biological ‘source’, foundation and basis (Doyle 1997: 87); and marks ‘the reduction of the human body to its constituent molecules’ (Hester 2016: 178). Ultimately, this new molecular ontology even extends beyond the human world to encompass *all* living entities, whose existence becomes grounded now in a common set of molecular ‘building blocks’. This is also the aspect of the ‘biological’ most readily captured by the widespread ‘bio’ framing.

At the same time, this molecular vision of life signals an equally profound *epistemological* shift. It asserts that the truth of this (biological) life can now be revealed through the specific knowledges and epistemes of the molecular – especially via the detailed study of the potentially vast combinations of DNA sequences that form ‘the information source for the operation of the cell’ (Kenney 1986: 20). ‘Molecular biology’, one of its most prominent pioneers put it plainly, ‘is nothing more than the search for explanations of the behaviour of living things in terms of the molecules that compose it’ (Brenner 1974: 785, cited in Kenney 1986: 18). Here the molecular vision of life thus begins to open up a whole new epistemology for *knowing* ‘life’ in which, as the sociologist Nikolas Rose puts it, life is now studied ‘as a set of intelligible vital mechanisms among molecular entities that can be identified, isolated, manipulated, mobilised, recombined, in new practices of intervention, which are no longer constrained by the apparent normativity of a natural vital order’ (Rose 2007: 5-6). This onto-epistemic shift towards the *molecular* marks a key permutation in the underlying *bios* of biopower, and one that has largely unfolded only *after* Foucault’s highly original studies were carried out (Dillon and Reid 2001).

All of this, moreover, suggests there is ultimately something ‘deeper’ at play in the emergence of the global bioeconomy that is not adequately captured by the widespread ‘bio’ framing. What matters most for the rise of the global bioeconomy, in the end, is not merely the ‘biological’ per se; but in fact a very specific way in which this biological is now understood and imagined as being inherently *molecular*. It is the detailed *molecular* knowledges, approaches and techniques in the life sciences that herald the prospect of creating new regimes of value based upon improved human understanding and control of biological processes. Indeed, all three of the major scientific and technological breakthroughs credited with underpinning the global bioeconomy – genetic engineering, DNA sequencing, and robotic technologies performing high-throughput molecule operations – are intimately bound up with the rise of the ‘molecular’ (White House 2012: 7). The case of ST-246 illustrates this point only all too well by, because it was precisely such molecular knowledges that allowed for the initial identification, as well as subsequent technical

optimisation, of a tiny new molecule that could interfere with the replication of smallpox viruses inside the host body (Grosenbach et al. 2011).

Kaushik Rajan is closest to acknowledging the pertinence of these molecular foundations of the global bioeconomy when he writes that biotechnology such as recombinant DNA technology 'allow the life sciences to become "technological", where the product that is produced is cellular or molecular matter such as DNA or protein', thereby opening up the very 'possibility and the rationale for this burgeoning biotechnology industry' (Rajan 2006: 5). Yet Michael Kenney manages to express this intimate connection between the bioeconomy and the molecular even more succinctly still: 'The core discipline for the biotechnology industry', he argues, 'is molecular biology….' (Kenney 1986: 10; see also Braun 2007; Hester 2016). The 'bio', in other words, is ultimately the 'molecular'; and the global 'bioeconomy' is therefore a political economy of molecules. If that is true, moreover, then it does become possible to suggest in earnest that the tiniest of molecules can engender a whole new political economy. In fact, the recent rise of the global bioeconomy is proof that they have *already*.

3. The Global Molecular Assemblage

The deeper insight gained from this genealogical excavation of the bioeconomy's molecular undercurrents is only short-lived however. It is quickly offset by three thorny conceptual challenges that immediately present themselves now, even though they largely remain unacknowledged in the literature. If the global bioeconomy is grounded in the molecular, and if it is molecules that ultimately connect all of these different actors, then how are we to theoretically incorporate the generative 'force' and even 'power' that molecules are exerting over these dynamics? We can no longer account for the rise of the global bioeconomy without accommodating the key role of the molecules that reside at its heart. How, furthermore, do we analytically reconcile the quite staggering, and even extreme, variations in scale that we are now left confronting? Macro-structures like states, markets and international institutions will somehow need to be conceptually connected to molecules so tiny that they cannot even be perceived by the naked human eye. How, finally, are we to do justice to the significant multiplication and diversification of pertinent actors that this molecular excavation also entails? In addition to governments and pharmaceutical companies, there are now so many other actors that need to be accommodated because they too work directly on, with, or through molecules. This includes a plethora of human actors like scientists, knowledge brokers, patent lawyers, judges, doctors, patients, editors of scientific journals, journalists, and so forth. Yet it also includes key material infrastructures like universities, hospitals, laboratories, and research funding bodies, as well as an array of less tangible and affective elements similarly bound

up with the world of molecules – like information, visualizations, techniques, desires, imaginaries, hopes, and fears (see Clough 2008). Excavating the molecular foundations of the bioeconomy produces deeper insight, but only at the cost of triggering a vexing cluster of new conceptual challenges not easily reducible to conventional state-market analysis.

One approach emerging across the social sciences that is particularly well suited for coming to grips with these kinds of conceptual challenges is assemblage thinking. Early adoptions of the notion of the 'assemblage' in the field of political economy tended to use the term mostly in a descriptive sense (see Sassen 2008; Abrahamsen and Williams 2009). Recently, more extensive engagements with assemblage theory have begun to explore the field of international finance (Schwittay 2011; McKeen-Edwards & Porter 2013; de Goede 2015). Yet assemblage thinking can also offer a useful, and even creative, resource for navigating the conceptual challenges around the political economy of molecules. Gilles Deleuze once famously defined an assemblage, with characteristic flair, as 'a multiplicity which is made up of many heterogeneous terms and which establishes liaisons, relations between them, across ages, sexes and reigns – different natures. Thus, the assemblage's only unity is that of a co-functioning: it is a symbiosis, a 'sympathy' (Deleuze and Parnet 2007). Expressed more prosaically, and bearing in mind that Deleuze himself never advanced a formal systematic theory of assemblages, an assemblage thus refers 'to any collection of heterogeneous elements that can be said to display some form of consistency and regularity while remaining open to transformative change through the addition or subtraction of elements or the reorganization of the relations between those elements' (Bousquet 2018: 167).

We will refer to this approach here as assemblage 'thinking' (as opposed to 'theory') in order to signal the fact that it deliberately represents more of an overall philosophical approach, idiom or ethos for thinking about the world, rather than a fully delimited analytical theory of political economy (for contrarian views see DeLanda 2016 and Nail 2017). As McFarlane and Anderson (2011: 126) argue in a different context, assemblage thinking is less about testing pre-existing hypotheses, and more about conceptual experimentation that 'opens the researcher up to risk, embraces uncertainty, expresses something of the fragility of composition, and strives to listen to what Deleuze and Guattari term "the sound of a contagious future, the murmur (rumeur) of new assemblages of desire, of machines, and of statements, that insert themselves into the old assemblages and break with them"'. Approached in this spirit, assemblage thinking offers considerable traction in navigating the three conceptual challenges that have just opened up in studying the global political economy of molecules.

First, the notion of the 'assemblage' is a particularly well calibrated analytical category for capturing the bioeconomy as a loose global formation encompassing a wide range (and very large

number) of heterogeneous actors all coalescing, in one way or another, around the molecular. An assemblage is thus neither a set of predetermined parts put together in orderly, sequential and pre-determined fashion; but neither is it merely a random collection of things (Wise 2011: 91). An assemblage is always 'a whole of some sort that expresses some identity and claims a territory. An assemblage is a process of becoming that brings elements together' (Wise 2011: 91). The properties of this 'whole' are necessarily emergent because they do not result just from aggregating the properties of its component parts; they also emerge from the detailed *interactions* that unfold amongst and between those component parts (Sesay et al. 2016: 5). With regard to the political economy of molecules, the notion of the 'assemblage' can thus usefully accommodate the presence of an extensive number of highly diverse actors, components, knowledges, and affective elements that all need to be conceptually accounted for, whilst at the same time capturing the fact that they are all loosely connected with one another through a common interest in molecules – thus also forming a kind of emergent unity expressed in the form of the global 'bioeconomy'.

Second, assemblage thinking is conceptually curious about the ways in which phenomena occurring at radically different scales can nevertheless connect and interact with one another in quite unexpected ways. Assemblage thinking can thus traverse quite extreme scalar variations 'by accounting for the successive embedding of smaller assemblages within larger assemblages and elucidating the connections between them…' (Sesay et al 2016: 5). More than that, and as the assemblage theorist Manuel DeLanda argues, '[b]ecause the ontological status of all assemblages is the same, entities operating at different scales can [also] directly interact with one another, individual to individual, a possibility that does not exist in a hierarchical ontology' (DeLanda 2016: 19-20). Assemblage thinking, in that sense, even 'requires a *democracy of scale'* (Harman 2014: 120, emphasis in the original). This aspect of assemblage thinking, too, is particularly attractive in the case of the global bioeconomy because it allows for the possibility that macro-structures like states, markets, and institutions might also be contoured by the tiniest of objects like molecules. Not only does assemblage thinking remain conceptually open to this possibility; its non-hierarchical ethos actively seeks out how phenomena occurring at radically different scales are nevertheless connected with one another in often quite unexpected ways.

Finally, assemblage thinking is also highly attentive to the role played by non-human elements or components in the world. One of the most controversial aspects of the approach (which it shares with Actor-Network Theory) is that assemblage thinking explicitly underscores 'the importance of the socio-material, i.e. that the world is made up of associations of human and non-human elements' (Müller and Schurr 2016: 218). From the perspective of assemblage thinking 'the "human" comes to be seen as a component, not the limit, of society' (Acuto and Curtis 2014: 2).

Assemblage thinking therefore does not deny the existence of human agency. In fact, assemblages frequently consist of a heterogeneous multitude of both 'subjects' and 'objects'. Yet the approach is ultimately much more interested in the relational co-functioning of those heterogeneous components as a composite whole (Sesay et al 2016: 3-4). That is also why assemblage thinking is conceptually quite comfortable with ascribing particular forms of 'agency' to non-human objects and artefacts as well. It understands 'agency' here not in the traditional humanistic way (i.e., with a restricted focus on human actors, intentionality and conscious reflexivity); 'agency' is instead understood more broadly 'as an effect or as the modification of a state of affairs', and as something that can encompass almost anything 'that has an impact and makes a difference in the world' (Bueger and Stockbruegger 2018: 50). All of this makes assemblage thinking inherently open to the possibility that objects and artefacts like molecules too can exhibit particular forms of 'agency' and 'power' in the global bioeconomy. As Deleuze once famously put it, the 'object itself is force, expression of force' (Deleuze 2006: 6).

Using those three methodological precepts developed through assemblage thinking – heterogeneity, exterior relationality, and multi-scalarity – we can thus summarily conceptualize the 'bioeconomy' as a dynamic molecular assemblage. In his careful theoretical reconstruction of Deleuze and Guattari's deliberately dispersed writings on assemblages, Thomas Nail (2017: 24) argues that the basic structure of assemblages is always made up of three components: their 'abstract machine' (conditions), their 'concrete assemblage' (elements), and their 'personae' (agents). The 'abstract machine' is what sets out the critical *exterior* relations that condition the various components of an assemblage – in this case the abstract notion of the 'bioeconomy' or 'bio-capital'. The 'concrete assemblage' is 'the existing embodiment of the assemblage', or a kind of 'skeletal' frame; in this case all the human, material and affective elements involved in the worldly play of molecules (Nail 2017: 26). That is also why conceptualizing the bioeconomy as a molecular assemblage does not, emphatically, imply that this assemblage consists *only* of molecules (themselves assemblages of atoms); it merely signals the fact that it is this common concern with molecules that places all of these heterogeneous components of the assemblage into a loose and unifying exterior relation. The 'personae', finally, refers to all 'the mobile operators that connect the concrete elements together according to their abstract relations' – in this case also those actors going about the labour of extracting different kinds of value from molecules (Niall 2017: 27). Yet because so many of these molecular connections are increasingly drawn at global scale, and because molecular rationalities move across (whilst also re-adapting to) different national contexts, we will ultimately conceptualize the bioeconomy as a *global* molecule assemblage (see Collier and Ong 2005: 11).

4. The Assemblage Within: Biodefense and the Valley of Death

To properly qualify as an assemblage, the global bioeconomy must also pass one final litmus test. Assemblages cannot be static or fully enclosed; they are 'never unifications, never totalizations, but rather consistencies or consolidations' (Deleuze and Guattari 1988: 589). Assemblages are inherently open systems because particular elements can always join and/or leave them, and because the relations amongst the components can change over time. An assemblage is thus 'precisely this increase in the dimensions of a multiplicity that necessarily changes in nature as it expands its connections' (Deleuze and Guattari 1988: 7; see also Hayden 1995: 294; Müller and Schurr 2016: 219; Dittmer 2017: 9-10). Such a process of further transformation in the global molecular assemblage is currently unfolding within the context of government efforts to better protect their populations and economies against a spectrum of health-based threats – like infectious disease outbreaks, the spectre of bioterrorism, and rising rates of anti-microbial resistance (Braun 2007; Cooper 2008; Lakoff and Collier 2008; Elbe 2014; Rushton and Youde 2014; Hester 2016).

One of the principal ways in which governments are trying to strengthen and enhance civilian biodefense is by developing an array of new pharmaceutical defences, or 'medical countermeasures', that can be rapidly distributed to the population in the event of an emergency. Here too governments thus want to harness the power of emergent molecular knowledges in order to proactively develop a whole arsenal of novel antibiotics, anti-virals, anti-toxins, antidotes, anti-bodies, and next-generation vaccines (Elbe 2018; Milne and Smith 2018). 'Our nation', extols the U.S. government in this vein, 'must have the nimble, flexible capability to produce medical countermeasures rapidly in the face of any attack or threat, whether known or unknown, novel or reemerging, natural or intentional' (PHEMCE 2013; Elbe et al. 2015). Ongoing efforts to procure those new medical countermeasures have recently spawned a whole new 'medical countermeasures' assemblage aimed at using molecular knowledges and technologies to generate additional *security* value.

The US government has been at the international forefront of those efforts; but even it initially struggled to procure such novel medical countermeasures. Pharmaceutical development is mostly undertaken by the private sector in accordance with market forces (Dumit 2012; Roy 2017); and there is no ready commercial market for medical countermeasures because they are aimed at quite rare and highly unpredictable diseases (Bartfai and Lees 2013; Elbe 2018). The few large pharmaceutical companies with the requisite knowledge, experience and financial clout to bring new pharmaceutical products to market thus tend to steer a wide berth around medical

countermeasures. Most promising new molecules with medical countermeasure potential (like ST-246) never see the light of day as a result; they remain perpetually stuck in the critical mid- to late-stages of pharmaceutical development – what industry experts metaphorically refer to as the 'valley of death' (Tucker 2009: 225; Hoyt 2012:155). The pharmaceutical industry's overriding desire for commercial profit thus prevents it from readily realizing the governments' desire for acquiring new medical countermeasures as part of their evolving national security strategies (Elbe 2018). Procuring new medical countermeasures is unlikely to succeed via the commercial bioeconomy route, and will require the development of a different kind of molecular assemblage.

Following a number of early and costly setbacks, the US government eventually decided to launch an ambitious new Public Health Emergency Medical Countermeasures Enterprise (Wizemann et al. 2010). The economic strategies underlying that new medical countermeasures 'enterprise' have not been subject to sustained analysis (Gronvall 2015; for a notable exception regarding vaccines see Hoyt 2012). Yet they reveal how the US government inventively drew upon several subtle strategies that it had earlier deployed in relation to the wider civilian economy. Behind the 'veil' of dominant public ideas about market fundamentalism in the United States, Fred Block (2008) argues, the federal government has long played a central role in financing and supporting the role of the private sector to commercialize new technologies – pointing to a 'hidden' and networked developmental state. In order to procure those desired new medical countermeasures, the US government now mobilized some of those same strategies, albeit adapting and re-combining them in new ways through a creative mix of formal institutionalization, targeted resourcing, and technological brokering (see Block 2008: 173; Block and Keller 2011). Collectively, those strategies have led to the creation of a specialized new medical countermeasures assemblage operating within the parameters of the wider global molecular assemblage – effectively spinning a new assemblage-within-an-assemblage for the purposes of civilian biodefense and national security.

As a first step, and echoing the earlier creation of other institutions like the Advanced Research Projects Agency (ARPA) during the Cold War, the US government created a specialized new government institution in 2006 that would assist pharmaceutical companies during the later stages of new medical countermeasure development (Block 2008: 175; Mazzucato 2013). The new institution is called the Biomedical Advanced Research and Development Authority (BARDA) and is the focal point now 'for the advanced development and acquisition of medical countermeasures to protect the American civilian population against CBRN [Chemical, Biological, Radiological, and Nuclear] and naturally occurring emergency threats to public health' (HHS 2016). BARDA is thus explicitly tasked by the government with helping (predominately smaller) pharmaceutical companies to shepherd their promising new molecules through the notorious 'valley of death' (Nicholson et al.

2016: 118). BARDA's role would effectively be to mimic many of the activities normally performed by a large pharmaceutical corporation in the overall process of new drug development (Elbe 2018; see also Caldwell and Howard 2014). As one official put it, BARDA's role is essentially to act as a virtual pharmaceutical company (Nicholson et al. 2016: 17). BARDA's creation thus marks the addition of a critical new institutional component to the global molecular assemblage.

Next BARDA began to draw new webs of exterior relations around key elements within that existing global molecular assemblage, so as to make the assemblage much more conducive to new medial countermeasure development. It altered, for example, the financial relations between those components through the provision of 'targeted resourcing' specifically for the late development stages of medical countermeasures, and whereby officials 'provide funding and other resources that have promising ideas for achieving breakthroughs' (Block 2008: 172). In the more conventional political economy of new drug development, the government usually only makes funding available to various actors (academic, government and also commercial) for carrying out basic research; but then it largely allows the market to 'freely' decide which products are taken forward for commercial development. Occasionally, the government may also provide wider non-financial incentives to energize research and development in particularly neglected disease areas. In the field of medical countermeasures, by contrast, up to 50 percent of the final contract can now be awarded to companies by the government via 'milestone' grants, and upon the successful achievement of intermediary development stages (HHS 2007:10). When it comes to medical countermeasures, pharmaceutical companies therefore no longer have to wait all the way until the very end of the drug development process before they can achieve revenues. Bringing the funding 'forward' in this way, and structuring the provision of government funding according to such 'milestone' payments, assists pharmaceutical companies in meeting the unforeseen changes in development costs, and helps them absorb some of the heightened technical development risk associated with new medical countermeasures. Yet it also deepens the extent to which the US government effectively becomes a risk-sharing 'partner' in the development of those new medical countermeasures.

In addition to recalibrating those financial relations surrounding new molecules with medical countermeasure potential, the US government also tweaked the way in which *technical expertise* flows through the global molecule assemblage. Advanced drug development is not just costly, but also riddled with complex technical challenges; and many of the smaller pharmaceutical companies interested in developing new medical countermeasures were evidently struggling to acquire the expertise required for overcoming all the technical, regulatory, manufacturing, commercialization, and business challenges involved (HHS 2011: 12). BARDA thus additionally introduced extensive technical support that it can provide to companies through its 'Core Services' – like the Clinical

Studies Network assisting companies with carrying out clinical trials for new medical countermeasures. A separate Nonclinical Development Network further helps pharmaceutical companies with developing viable animal models, because it can be very difficult to carry out human clinical trials on some deadly diseases due to the dangers and ethical concerns it would give rise to (Smith 2013). BARDA is even able to provide pharmaceutical companies with access to relevant 'subject matter experts', which BARDA often hires following many years of high-level experience in the private pharmaceutical industry. These measures have mostly been introduced piecemeal by the US government through a protracted process of trial and error. Yet collectively they have ended up spawning what is now effectively an 'exceptional' molecular assemblage operating specifically for new medical countermeasures in the United States (see Elbe et al. 2015).

Molecules like ST-246 have already 'benefitted' extensively from this new medical countermeasures assemblage. Like many new molecules in commercial biomedicine, ST-246 received early government support (via the National Institute of Allergy and Infectious Diseases and the US Department of Defense) worth around US$ 115 million (HHS News 2011; Love 2011). Unlike other molecules destined for clinical biomedicine, however, Siga Technologies subsequently received a further multi-year contract from BARDA worth nearly half a billion dollars for the advanced development of the molecule (HHS News 2011). With the help of this additional support, ST-246 managed to navigate the notorious 'valley of death' and, over the course of many years, became transformed into a new medical countermeasure – a small-molecule antiviral pill called TPOXX® (tecovirimat), and which received official FDA approval in July 2018 (FDA 2018). At the time of writing, BARDA is already acquiring nearly two million courses of TPOXX® for its Strategic National Stockpile (SNS) of medical countermeasures through another multi-year contract valued at up to US$ 629 million (SIGA 2018). Yet ST-246 is also merely one of many such new molecules. BARDA reports that in the decade following its inception, it has been involved in a total of 24 medical countermeasures that have been cleared, approved, or licensed (Hatchett 2016: 5). Furthermore, BARDA has also provided wider support for the research and development of more than 180 medical countermeasures (Fassbender 2016).

All of those newly developed medical countermeasures demonstrate how, via the creation the new medical countermeasures enterprise, the US government has been able to harness the power of molecules to create additional and novel forms of 'bio-value' in the area of national security. Yet the government could only do so through the careful reconfiguration of state-market relations for the specific purposes of civilian biodefense – reconfigurations which reverberate far beyond the territorial borders of the United States. For, those new knowledges and technologies created through this US medical countermeasure enterprise can also be shared with other countries

around the world during global health emergencies, whilst other governments with the requisite resources may similarly decide to purchase some of these new medical countermeasures for their own national stockpiles. Much of this acquired medical countermeasures expertise is also already informing much broader international public-private initiatives aimed at speeding up the development of new medicines and vaccines during global health emergencies – such as the international Coalition for Epidemic Preparedness Innovations (CEPI). It is, moreover, being increasingly applied to stimulate greater pharmaceutical innovation in relation to other pressing global health challenges like anti-microbial resistance (AMR).

More broadly, the creation of this new medical countermeasures enterprise also marks a powerful illustration of how the emergent properties of assemblages can change due to the addition of new elements, and through the surfacing of new relations between components within the assemblage (Sesay et al 2016: 5). The new US medical countermeasures enterprise has not been created 'from scratch'; nor has it been set up as a covert government program working outside of the parameters of the commercial bioeconomy. Rather, it has come about by drawing upon, and even openly working with, exactly the same components that already exist within the global molecular assemblage – like pharmaceutical companies, scientists, regulators, and so forth. In order to direct these existing elements towards the desired goal of developing of new medical countermeasures, the US government has 'simply' added a critical new institutional component to this wider molecular assemblage (in the form of BARDA), and begun to spin a new set of *exterior* relations (financial, technical, regulatory) around those existing elements. The new US medical countermeasures enterprise has effectively been spun out of (and within) the already existing molecular assemblage that is the global bioeconomy.

That is also why the medical countermeasures enterprise does not, in the end, simply mark another chapter in the familiar 'spin-off' story, whereby innovative defence technologies end up producing economically beneficial applications – from jet engines, radar, and anti-biotics, through to nuclear technology, microchips and the internet (Ferry and Sulston 2002: 22). In fact, the medical countermeasures enterprise works exactly the opposite way around. In what Linda Weiss (2014) calls 'spin-on', the state draws upon new technologies emerging in the commercial or civilian sphere in order to develop new technologies that also strengthen its national security, and through which it can project its power abroad (Weiss 2014: 10). It is, in other words, not so much that new defence-related medical countermeasures are spilling over into the civilian bioeconomy, but conversely that the civilian bio-economy is being productively harnessed in order to develop new technologies for the purposes of strengthening civilian bio-defence. The US medical countermeasures enterprise is essentially a highly specialized biodefense assemblage operating now within the confines of the

wider commercial assemblage for biomedicines. It marks a key transformation within this global molecular assemblage, whilst simultaneously existing in deep symbiosis with it. Yet it also shows how the tiniest of molecules have, in the end, managed to engender not just *a* new political economy in the form of the global bioeconomy; but in fact *multiple* ones operating concurrently now across the fields of commercial biomedicine and national security.

Conclusion

What does the study of international political economy gain from attending to this lively play of molecules in the world? First and foremost, analysing the political economy of molecules advances the post-Foucauldian study of biopolitics. Whilst building upon Foucault's earlier work on biopower, this approach explores how the operations of biopower are also changing because the 'vital epistemics' of the life sciences have further evolved and transformed since he first penned those influential studies. Biopower today no longer operates solely along the axes of the individual human body or the population in the way Foucault originally postulated. It now also operates through the logics and scale of the molecular; and just as the extraction of human labour under capitalism required the development of new tactics and strategies governing the body, so too the subsequent shift to the 'molecular' bioeconomy has triggered modifications, re-configurations, and further re-contouring of state-market relations. Those, we have seen, include the increased flow of public funding to the life science for generating new molecular knowledges, the rise and intensification of *intellectual* property to enable the commodification of such molecular technologies, the development and geographic expansion of new regimes for the international protection of such intellectual property, and the creation of new political economies specifically for medical countermeasures development in the area of civilian biodefense. Studying the political economy of molecules thus reveals that it is not merely 'life' itself, or indeed the 'biological' more generally, that is pertinent to political economy. *How* exactly we come to think about and *know* 'life' actually matters just as profoundly in the end.

Nor is there any reason to assume that this 'molecular' shift will be the last such permutation in the underlying *bios* of biopower. Moving forward, the study of international political economy will also have to explore how other significant transformations in those 'vital epistemics' come to contour political economy. Scientific 'anomalies' are already beginning to accumulate at the frontiers of biology, particularly in the fields of epigenetics and genomics, that are leading some scientists to openly question the 'central dogma' of molecular biology, and who are now pointing to the need to return to more holistic understandings of cell and life processes (see Shapiro 2009).

There are, in other words, likely to be further shifts in our 'vital epistemics' to come, and with potentially equally significant ramifications for political economy. Even the broader notion of 'life' itself possesses historicity in the end. Indeed, it is easy to forget that as late as the eighteenth century the concept of 'life itself did not exist. All that existed was living beings, which were viewed through a grid of knowledge constituted by natural history' (Foucault 2005 :139). Looking forward, we must therefore ask not just what might come 'after' the molecular framing of life; but also what comes after 'life' itself?

Attending to the play of molecules in the world also challenges, secondly, the division between the human and the non-human worlds in the study of political economy. Molecules exist both within and outside of the human body, and continuously traverse the boundary between the human and the non-human worlds. Indeed, the molecular vision of life powerfully reconnects human existence with the wider natural world by reconceptualising and re-coding *all* things living on this planet as being united, traversed and defined by common 'molecular' foundations. Looking back from the vantage point of this molecular perspective, Foucault's account of biopower thus begins to appear unduly anthropocentric, with its particular focus on individual human bodies (discipline) and the collective body of the population (biopolitics). Attending to the 'molecular', by contrast, moves the analysis of biopower in a decidedly more post-human direction by cultivating greater sensitivity to the intricate relationship between human life and the wider natural world (Haraway 1997; Hayles 1999; Barad 2007; Thacker 2009; Wolfe 2010; Braidotti 2013).

Approaching the study of political economy with such a post-human sensibility further opens up the possibility that non-human objects and artefacts – like molecules – can also possess particular kinds of agency in the world. Their 'agency' is evidently not a traditional humanistic one, conceived of as a deliberative and reflexive capacity located 'inside' any particular agent. On the contrary, the 'agency', 'power', or 'force' of molecules stems precisely from all of the *exterior* relations that coalesce around, emerge from, converge upon, and flow through them. 'Power', McKeen-Edwards and Porter (2013: 26) argue, 'does not only involve the absolute possession of deployable capabilities by an actor, but also involves the ability of actors to enrol networks of human and objects that might be engaged in other activities'. Molecules exhibit such a distributed enrolment power by provoking a wide and diverse array of actors to coalesce around them in the quest to create new forms of commercial and security value. By their very existence molecules have thus engendered what Deleuze and Guattari (1984) once referred to as 'desiring machines', and have brought about systematic shifts in state-market relations across the fields of both global health and biodefense. Yet these are just two, if highly significant, domains amongst many; and there is still plenty of scope to further explore the political economy of molecules in other prominent 'bio'-

domains that similarly form part of the global molecular assemblage – like agriculture, food production, climate management, energy security, biofuels, and so forth. Such further research too would help to show just how much molecules have come to matter, how the world is a different place today because of the discovery of molecules, and how we therefore need to cultivate a more post-human international political economy.

All of this, finally, will also require new and creative approaches for studying international political economy. Tracing the lively, forceful and post-human play of molecules has quickly unearthed a vexing constellation of challenges that resist easy conceptualization, but that will undoubtedly also resonate in other areas of political economy. Those include the ways in which heterogeneous human and non-human actors come together to form loose and open-ended unities, how phenomena and processes connect with each other across extreme scalar variations, and the role of desire in driving the transformation and adaptation of assemblages. Assemblage thinking has been able to help navigate many of those challenges. Along the way, it has opened up creative ways of thinking about 'agency' and 'power', whilst also challenging some of the long-standing hierarchies and binaries in the field (e.g. micro/macro, non-human/human, desire/reason). Much like we can start reading a map from pretty much any point on it, so too assemblage thinking reveals the multiple ways and scales at which we can enter the study of international political economy. Moving forward, assemblage thinking thus shows considerable promise for enhancing the field's ability to identify unconventional, multi-scalar and hitherto overlooked connections in the study of political economy – making for a livelier and more experimental study of political economy, even rendering it strange once more.

In relation to the political economy of molecules, those methodological precepts developed through assemblage thinking have already revealed that political economy is *always* shaped and contoured by the generative force of our deeper onto-epistemic conceptions of life. That, in the end, marks another reason why markets can never be completely 'free'. Not only do markets always require some form of government support for their creation and 'smooth' functioning. Not only do 'free' markets also demand extensive government intervention to fulfil an array of needs in the area of national security. Markets are also never completely free because they are always already bounded by our deeper understandings of life. Perhaps nothing is more central to political economy in the end than the idea that life has a truth, and that we can come to know this truth. In this way, assemblage thinking has even ended up – quite inadvertently – revealing the value of 'life'.

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